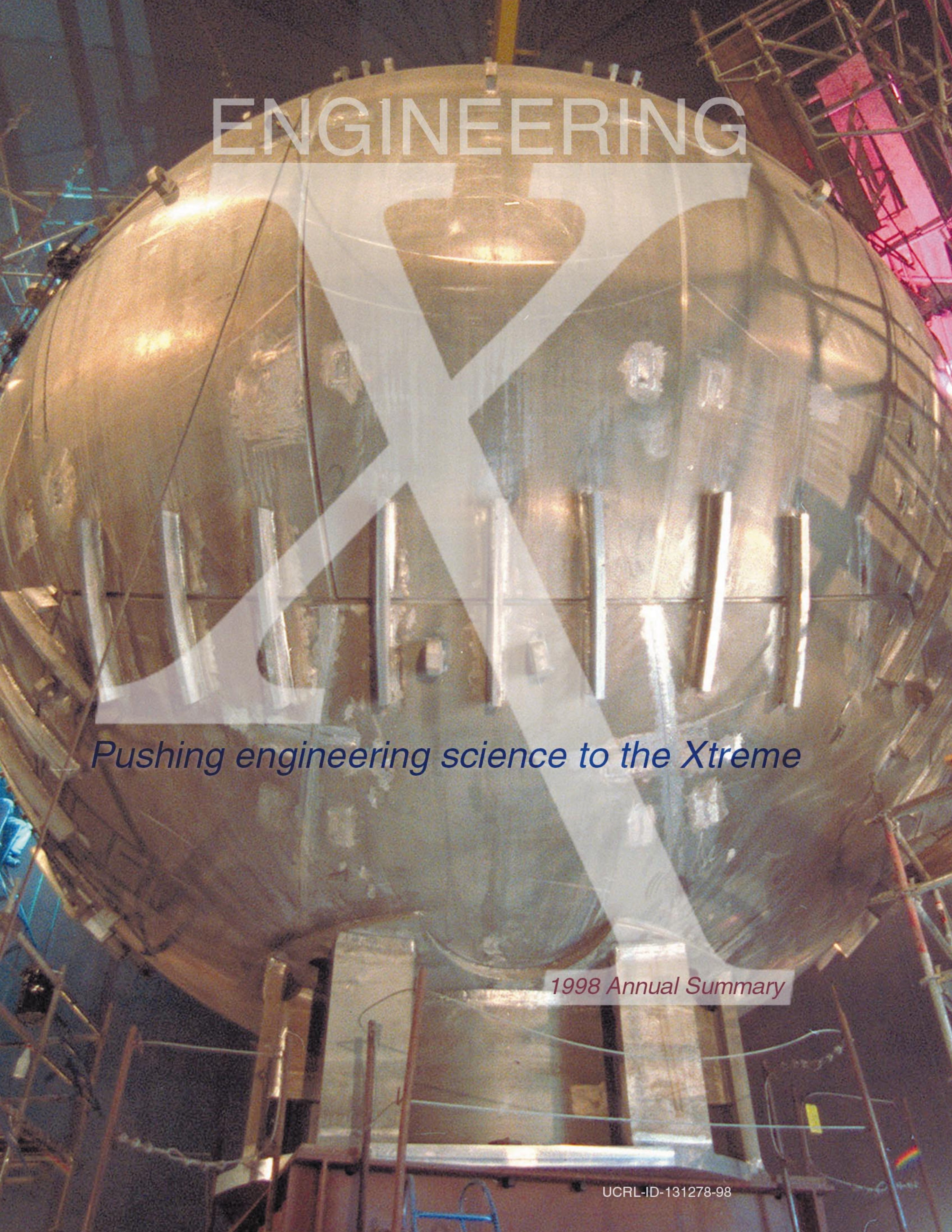


ENGINEERING X

Pushing engineering science to the Xtreme

1998 Annual Summary

UCRL-ID-131278-98

Contents

On the cover: The 10-m-diameter target chamber for the National Ignition Facility was assembled in sections and welded together into its final configuration. NIF is the world's largest, most precisely fabricated, and most powerful laser—an example of both microscale and ultrascale Xtreme Engineering.

LLNL Engineering, 925-422-8351
Managed by the University of California for the Department of Energy

Message from the Associate Director

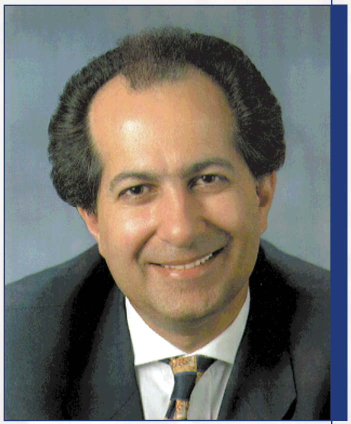
Fiscal year 1998 in Engineering was marked by competing priorities to meet critical Laboratory programmatic milestones, extend Engineering's internal restructuring to promote more long-term technological growth, and recruit highly motivated technical staff in an increasingly competitive environment.

I believe that the urgencies were greater and the technical problems more demanding this year, pushing us to work harder and faster than any other time in my tenure here. I am pleased to report that we met every key milestone and achieved numerous technological breakthroughs, as this *Summary* will show.

In the programmatic areas, demands presented by our customers peaked simultaneously. In the lasers area, we completed most of the detailed designs for the $1.2-billion National Ignition Facility (NIF) on time, paving the way for the timely procurement of components and structures for this mammoth laser, to be ready to operate in 2002. In the defense area, our effort in the last 24 months successfully culminated in the first-ever combined flight test of the W87/Air Force Peacekeeper missile in an instrumented mode with a high-fidelity unit.

Concurrently, the Laboratory's industrially sponsored activities in atomic vapor laser isotope separation and extreme ultra-violet lithography reached critical stages of activity, which required significant Engineering resources. In the biosciences area, LLNL greatly expanded its activities in the human genome sequencing area, with the establishment of the Walnut Creek (California) sequencing factory.

At the same time, we leveraged our competence in microsystems and biosciences to establish a robust technical presence in the field of biological and chemical weapons defense. In the "Technical Accomplishments" section of this report, you can read more about the antiterrorist instruments we have built that yield an unprecedented detection rate.



Spiros Dimolitsas

In the operations area, Engineering underwent an important change in its technology investment strategy. In 1998, we consolidated our nine technical thrust areas into five Engineering Technology Centers, and restructured these centers to form the Engineering Science and Technology Program reporting directly to my office. We expect to name the five permanent Center directors in the first quarter of 1999.

In parallel, we significantly expanded our recruiting and worked with the institution to increase our ability to make capital investments and modernize our tools in non-programmatic areas. This report summarizes our 1998 accomplishments. I hope you will find it both interesting and informative.

Engineering Today

Unlike most research and development laboratories, Lawrence Livermore National Laboratory (LLNL) is responsible for delivering production-ready designs. Unlike most industry, LLNL is responsible for R&D that must significantly increase the nation's security.

This rare combination of production engineering expertise and national R&D agenda identifies LLNL as one of the few organizations today that conducts cutting-edge engineering on grand-scale problems, while facing enormous technical risk and undergoing diligent scrutiny of its budget, schedule, and performance.

Xtreme Engineering

On the grand scale, cutting-edge technologies are emerging from our recent ventures into **"Xtreme Engineering™."** Basically, we must integrate and extend technologies concurrently and then push them to their extreme, such as building very large structures but aligning them with extreme precision. As we extend these technologies, we push the boundaries of engineering capabilities at both poles: microscale and ultrascale.

Today, in the ultrascale realm, we are building NIF, the world's largest laser, which demands one of the world's most complex operating systems with 9000 motors integrated through over 500 computers to control 60,000 points for every laser shot.

On the other pole, we have fabricated the world's smallest surgical tools and the smallest instruments for detecting biological and chemical agents used by antiterrorists.

Later in this *Annual Summary,* we highlight some of our recent innovations in the area of **Xtreme Engineering**, including large-scale computer simulations of massive structures such as major bridges to prepare retrofitting designs to withstand earthquakes. Another feature is our conceptual breakthrough in developing the world's fastest airplane, HyperSoar, which can reach anywhere in the planet in two hours at speeds of 6700 mph.

Other Recent Highlights

In the last few years, Engineering has significantly pushed the technology in structural mechanics and micro-instrumentation. For example, our DYNA code is widely used both by government and industry to model the behavior of structures under large deformation conditions, such as automobile and aircraft collisions. Today, our codes have expanded to run on the world's most powerful Tflop/s class computer, in the massively parallel, coupled/-multi-physics domain.

More recently, in microtechnology, we have been designing and fabricating unique microinstruments using lithographic processing. Building on Engineering's pioneering work in precision engineering, we are now able to fabricate complete biomedical and biochemical instruments, often at far less than one-tenth size, with improved performance over current "state-of-the-art" laboratory instruments.

These developments are helping us make unique contributions in the fields of proximal and remote sensing related to nonproliferation and counterproliferation of weapons of mass destruction (such as nuclear, chemical, and biological weapons) and in biotechnology, where we actively support LLNL's significant involvement in human genome sequencing.

Partnering with Industry

In 1998, LLNL further expanded its work with industry, initiating the $250-million extreme ultra-violet lithography (EUVL) project to develop the next generation of process technology for sub-0.1-μm semiconduction fabrication, the so-called "next-generation computer chip." The EUVL project also represents a unique partnership of a national laboratory with industry (Intel, AMD, Motorola) and may soon yield international partners.

A similar pioneering venture spearheaded by Engineering teams LLNL with GST Communications, Nortel Networks, and Sprint in the National Transparent Optical Network Consortium to create the $120-million "next-generation Internet" or "SuperNet" on the west coast. This project is funded by the federal Defense Advanced Research Projects Agency.

Profile of LLNL Engineering

Almost one-third of the Laboratory's 7500 full-time employees belong to LLNL Engineering. Our current staff of almost 2200—combining expertise in mechanical, nuclear, chemical, electrical, electronics, materials, civil, and other types of engineering—is one of the largest engineering R&D operations in the country. Approximately 1800 are typically assigned or matrixed to work directly with Laboratory programs or other organizations.

In 1998, the Laboratory's revenues were nearly $1.3 billion with $4 billion of capital invested in plant and research facilities. Within LLNL, Engineering is a $400-million business.

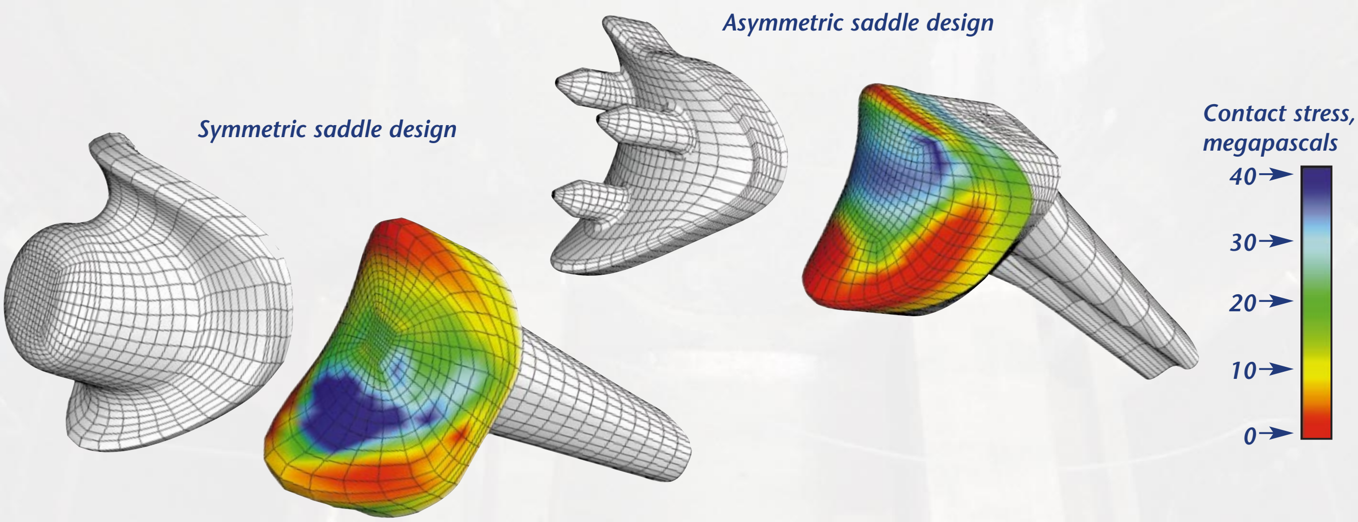
Considered one of the world's premier applied-science national security laboratories, LLNL must assure, through the design, development, and stewardship of nuclear weapons, that the nation's stockpile remains safe, secure, and reliable, while preventing the spread and use of nuclear weapons world-wide. This national security mission is complemented by programs in energy, environment, biosciences, and the basic sciences.

The mission of LLNL Engineering is to turn physics ideas in these five areas into reality. In actuality, this means Engineering undertakes the design for most Laboratory end-deliverables (such as weapons, where LLNL has design-to-retirement responsibility). Furthermore, Engineering designs and builds most of the Lab's unique experimental facilities, such as the High Explosives Applications Facility. Finally, Engineering conducts research into advanced, broad-application technologies that enhance the Laboratory's overall ability to ensure its national security mission.

New Engineering Technology Centers

To promote this third goal, pursuing advanced technologies, in 1998, Engineering was restructured to include five new Engineering Technology Centers. (For an overview of the new structure refer to the organization chart on page 12.) These Centers complement our current departments in mechanical and electronics engineering.

LLNL Engineering remains a multidisciplinary organization with expertise in most of the major engineering fields. Its wide-ranging capabilities are a direct outgrowth of Livermore's nuclear weapons work and the interdependence of weapons design, computational modeling, engineering, safety, and performance. Engineering personnel simulate engineering systems, improve systems designs, and test performance when built. In addition, Engineering manages numerous large- and small-scale projects requiring complex interactions among many scientific disciplines.



Livermore-developed NIKE3D is used in the biomedical field for finite-element analyses of thumb carpo–metacarpal joint implants. Colored areas show reaction forces experienced by the implants as they would grasp a house key.

Engineering's Core Competencies and Activities

Engineering's core competencies focus on:

- Integrated engineering of large-scale, complex, applied physics systems;
- Large, complex computation modeling and simulation;
- Microscale engineering;
- Measurement science at extreme dimensionalities.

These competencies are represented by a number of activity areas, which include:

- Nuclear and conventional weapons engineering,
- Lasers systems engineering,
- Safety-critical control systems,
- Adaptive and high-precision optics,
- Electronic commerce and concurrent engineering,
- Structural, thermal, and fluid system analysis and design,
- Information systems vulnerability analysis,
- Integrated photonics,
- Accelerator and microwave electronics,
- Opto-electronic communication devices,
- Real-time data acquisition and processing,
- Remote characterization and detection systems,
- Adaptive sensors and networks,
- Geologic signal processing and analysis,
- Biomedical imaging,
- Nondestructive evaluation.

Engineering Facilities

Engineering owns and operates 30 facilities at the main one-mile-square site in Livermore, California, about 45 minutes east of San Francisco. These total 770,000 gross square feet, with 70% dedicated to working engineering laboratories, shops, and computer equipment and storage space, and the remaining devoted to office space. In addition, Engineering operates 36 buildings and magazines at Site 300, a 45-mile-square test site about 30 minutes away that LLNL manages.

Technical Accomplishments

First-ever combined W87/ Air Force missile flight-tested

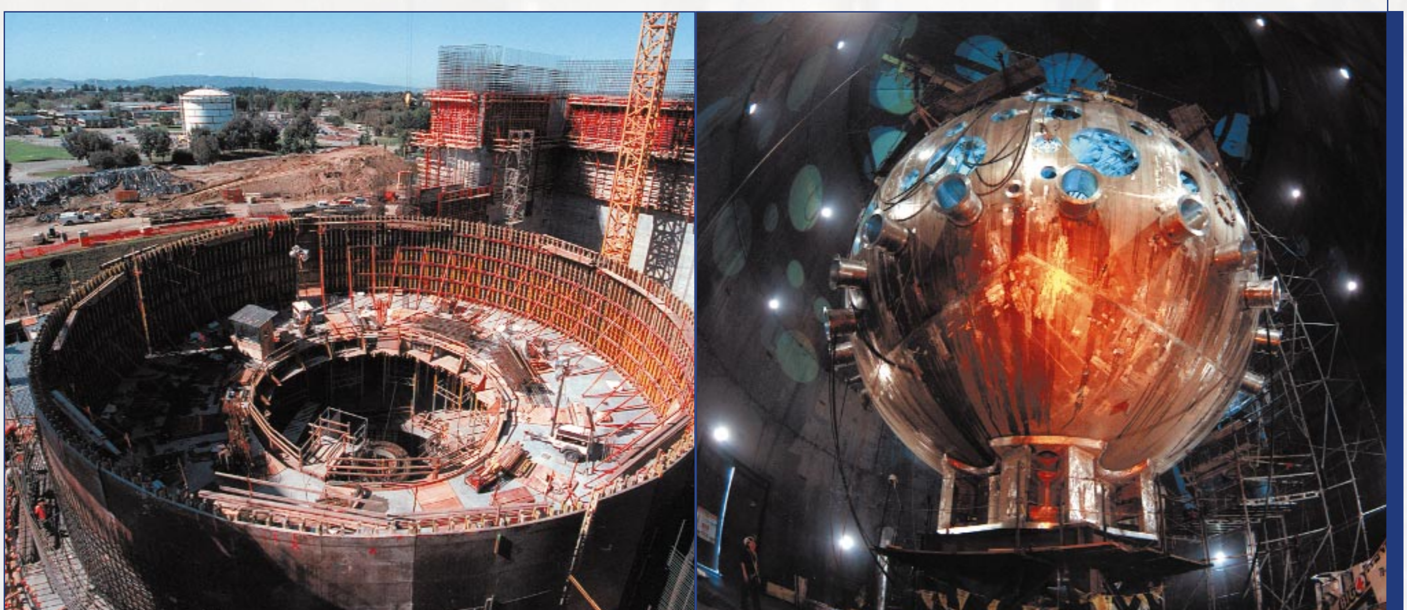
In May, LLNL Engineering conducted the first-ever combined flight test of a high-fidelity warhead with on-board instrumentation. The W87/Air Force Peacekeeper missile flew from Vandenberg Air Force Base to the Kwajalein Missile Range.

Preparations included major design and instrumentation of high-fidelity test assemblies, advanced in-flight instrumentation and diagnostics, and down-range data acquisition systems. Major ground tests of the assembly design were also included. A second flight is scheduled for March 1999, which will test a new series of instrumented high-fidelity assemblies.

NIF completes design reviews; awards equipment contracts

Fiscal year 1998 was a period of intensive engineering design for the National Ignition Facility (NIF). Progress, as measured by Department of Energy performance measurement milestones, was excellent: 85 of the 95 milestones were met. Many of the achieved milestones were project design reviews for special equipment (non-conventional facilities), involving major participation by Engineering personnel and chaired in many cases by Engineering managers.

Representative of the final design reviews were reviews of the optical pulse-generation system, the amplifier system, the Pockels cell, the beam transport vessels and enclosures,



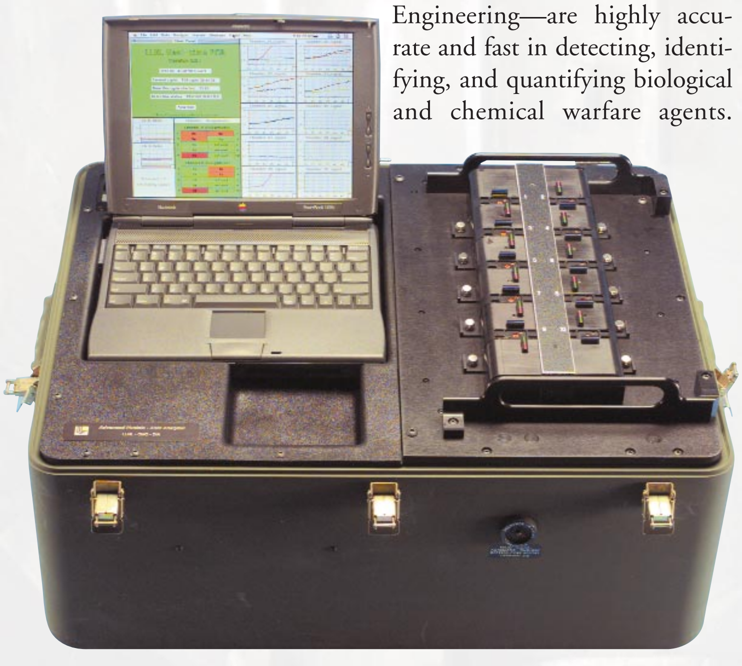
The 10-m-diameter target chamber for the National Ignition Facility will focus the enormous energy of this laser system on a 2-mm-sized target. On the left is the base for the target chamber, and on the right is the target chamber. When the chamber is complete, it will be lowered onto the base.

the laser support structures, the computer system, the optical mounts, the final optics system, the target chamber, and the major optical components (amplifier slabs, lenses, mirrors, polarizers, and frequency-conversion crystals).

The special equipment designs were supported by extensive computational analyses—structural, vibrational, and thermal—to demonstrate safety in both normal and off-normal (e.g., seismic) environments and system performance with respect to alignment and stability. Following the final design and procurement reviews, procurements were awarded for the target chamber, the spatial filter vacuum vessels, the laser bay and switchyard steel support structures, the frequency-conversion rapid-crystal-growth facility, and the amplifier-glass production.

Counterterrorism instruments show highest performance

Three successive field trials at the Dugway Proving Grounds demonstrated that two new instruments—invented, designed, patented, and tested by LLNL Engineering—are highly accurate and fast in detecting, identifying, and quantifying biological and chemical warfare agents. The instruments are based on two proprietary technologies: the flow-stream-waveguide flow cytometer and the silicon-sleeve-based polymerase chain reaction. Called "miniFlo" and "miniPCR," these two instruments check antibody-based assays and nucleic-acid based assays, respectively.



The "miniPCR," an instrument for biological and chemical assay, is not only portable but also much faster and more energy-efficient than bench-top models.

Both portable instruments have detected, identified, and quantified unknowns containing bacterial agents over the range of 10^6/ml through 10^3/ml with negligible false positives and negatives, a level of performance unmatched by other instruments.

Subcritical testing for BAGPIPE and CLARINET completed at NTS

LLNL Engineering was responsible for the design and assembly of the containment features, experiment packages, diagnostics, controls, and safety interlock system for the successful BAGPIPE and CLARINET underground scientific experiments at the Nevada Test Site (NTS). These experiments involved high explosives and less than critical masses of special nuclear material. All timing, firing, and controls worked at the 100% level, and all imaging and velocimetry data were successfully captured. LLNL Engineering also provided project management, mechanical support, and field oversight for both experiments.

BAGPIPE and CLARINET were the second and third in a series of subcritical experiments designed to validate different measurement capabilities that will be employed for future underground experiments. Although the diagnostics had been extensively tested with inert materials at other facilities, they had not yet been validated with materials of primary interest to the stockpile stewardship program.

The experiments also returned valuable data related to the complex behaviors of metal surfaces and subsurfaces resulting from high-explosive shock conditions. This information will be used to benchmark computer codes, allowing scientists to better predict the performance, safety, and reliability of stockpile nuclear weapons.

Information security center launched

Late this year, LLNL Engineering, with the Computation and the Nonproliferation, Arms Control, and International Security directorates, formed the Center for Information Operations and Assurance. The new center will address national security implications of the rapidly growing field of global computing and communication networks.

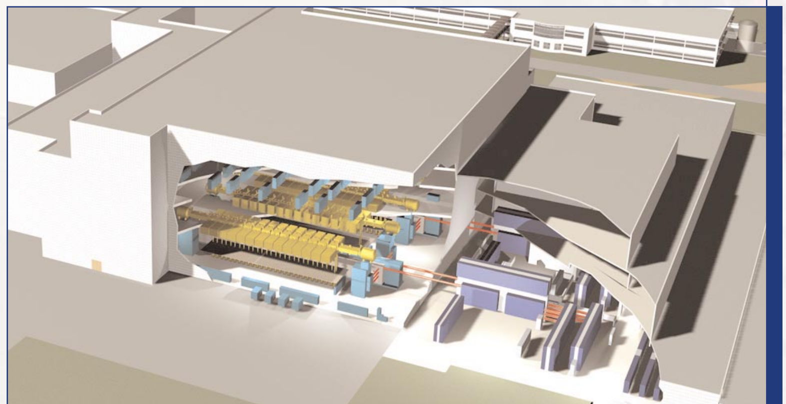
The new center will couple activities of the Computer Security Technology Center with the emerging technologies resulting from the Information Operations, Warfare, and Assurance (IOWA) project. IOWA was launched earlier in the year with a $1.4-million Director's Strategic Initiative and triggered funding from external agencies. Engineering led this multidisciplinary effort.

Accelerated separator milestone for uranium separation reached

The largest technology transfer project at LLNL, the Atomic Vapor Laser Isotope Separation (AVLIS) process for the United States Enrichment Corporation (USEC), reached a major milestone in 1998 with the privatization of USEC. Through an initial public offering, the U.S. government sold its entire interest in USEC. USEC intends to have an AVLIS enrichment plant in operation by the early 2000s.

The Laboratory has been developing the AVLIS technology for more than two decades with scientific principles and bench-scale experiments, progressing to production-plant-scale equipment. Over the course of 1998, Engineering personnel supported an accelerated schedule for the AVLIS separator and laser system engineering development, deployment, and testing.

Engineering activities during 1998 focused specifically on developing long-life critical separator subsystems that involve difficult material and design challenges. The separator's vaporizer system achieved high efficiency levels as a result of a number of upgrades to the magnet package and e-beam power supply, and laser system beam quality was increased as a result of modifications. The successful development of solid-state lasers continued with significant potential economic savings compared to copper lasers.



The AVLIS Plant will provide the world's least costly fuel for electric power generation.

EUVL "next-generation computer chip" earns top ranking

By exceeding a wide range of ambitious technical goals, the Virtual National Laboratory team of LLNL, Sandia, and Lawrence Berkeley National Laboratory has been recognized by Sematech as having moved the concept of EUVL into the lead of technologies competing to be the Next-Generation Lithography (NGL) system for the manufacturing of semiconductors. Sematech is the primary international semiconductor industry research consortium, with leading U.S. semiconductor manufacturers as members.

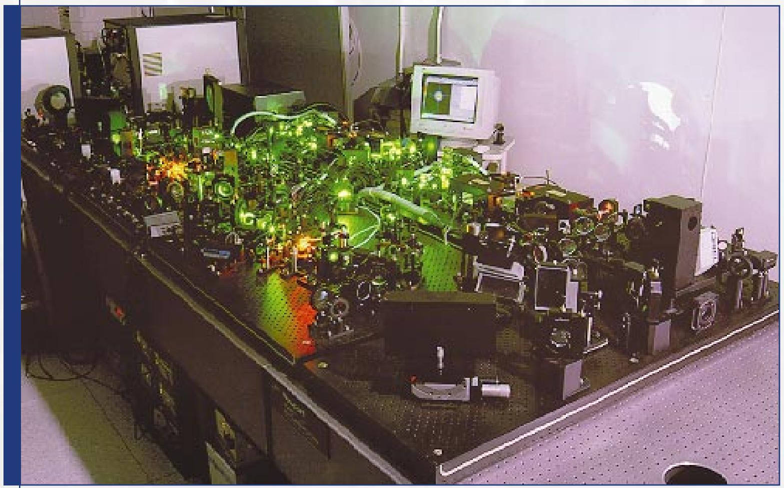
Extreme ultra-violet lithography opens the prospect of computer chips ten times more powerful yet one-tenth the size of today's chips. The Laboratory and its partners have designed an EUVL process that is a 100,000-fold improvement over conventional methods.

This high ranking of EUVL by Sematech is significant because future manufacturing plans and investments by the entire semiconductor industry are strongly influenced by this assessment of the relative viability of the various technologies being pursued for NGL.

LLNL engineers led several teams engaged in key developments that have enabled the EUVL project to achieve this ranking. These developments include optical fabrication, multilayer reflective coatings, precision optical mounting and alignment, and low-defect mask fabrication. Working with industrial partners, Engineering-led teams have produced a set of four off-axis aspheric mirrors with figure accuracies of better than 0.5 nm and with high spatial frequency surface roughness of less than 0.3 nm (about one atom).

Unique laser-cutting workstation delivered to Oak Ridge

The two-year development of a unique laser-cutting workstation was completed in August, and the machine has been delivered and reassembled at Y-12 in Oak Ridge as part of a weapons production complex modernization program.



The laser-cutting workstation removes material atom by atom and effectively causes no heat. This technology can be used for a range of cutting applications, from high-explosive materials to tooth enamel and heart tissue.

Called the Laser Cutter Work Station (LCWS), the device, which is installed in a temperature-controlled environment, performs high-precision cutting through the weld of expensive parts to enable their subsequent reuse or recovery. The LCWS consists of two major subsystems: the Workpiece Alignment Station (WPAS) and the Laser Cutting Station (LCS). The LCWS control system provides integrated, computerized system-wide control.

The WPAS uses ultrasonic sensor technology to locate the weld step and mark the part. Based on guidance from the ultrasonic measurement, a computer-controlled set of tip/tilt positioning stages, then orients the part for marking by inkjet. The part is placed onto the LCS turntable, where it is aligned via computer. Then, the vessel is pumped down, and the laser-cutting begins. Diagnostic cameras monitor the cut and determine when "weld cut-through" has occurred. A negative air-flow system in the vessel ensures that any particulates from the cut are vented through HEPA filters.

HyperSoar aircraft designed to reach anywhere on Earth in two hours

LLNL Engineering has completed the conceptual design of the world's fastest plane, HyperSoar. This vehicle would travel at the edges of the atmosphere at 6700 mph or Mach 10 (10 times the speed of sound). By using a skipping motion, the aircraft is able to avoid the heat of the atmosphere.

HyperSoar, which could fly anywhere on Earth in less than two hours, is intended for commercialization. The plane could carry 500 passengers at an affordable price. However, HyperSoar will most likely be used first for military applications.

A rendering of the new aircraft was featured on the cover of the Sept. 7, 1998, edition of *Aviation Week*, and the aircraft has been the subject of many print and media news reports.

First airborne imaging spectrometer demonstrated

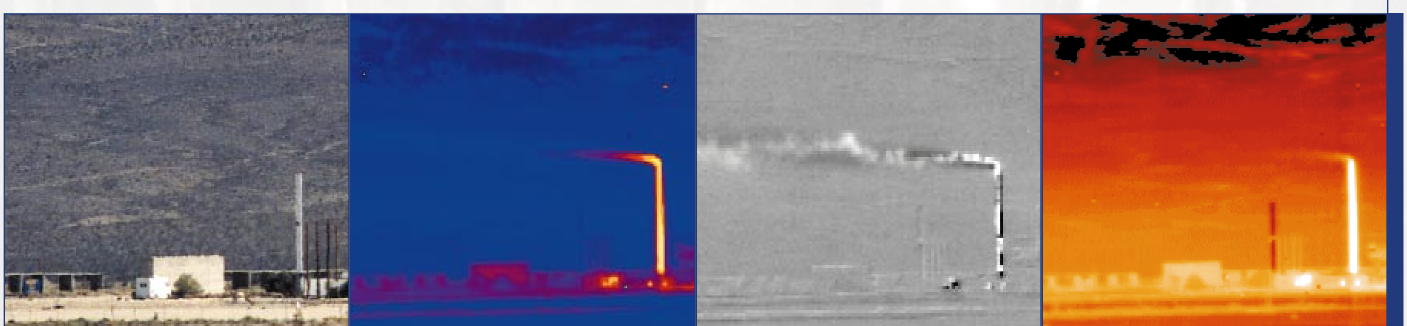
In 1998, LLNL Engineering teamed with technical counterparts in the Nonproliferation, Arms Control and International Security (NAI), Physics and Space Technology (P&ST), and Computation directorates to develop and demonstrate the novel airborne Hyperspectral InfraRed Imaging Spectrometer (HIRIS), which uses new technology to collect and detect chemicals. This complex electro-optical instrument was integrated into a Cessna Citation II jet aircraft, and performed near predicted levels during a summer collection series. These collections targeted the well-characterized gas releases from the LLNL-developed Remote Sensing Test Range at the Nevada Test Site.

HIRIS is a state-of-the-art hyperspectral imaging spectrometer that provides simultaneous spatial, spectral, and temporal information in the longwave infrared "fingerprint" regime. Infrared hyperspectral systems can detect, locate, identify, and quantify invisible trace chemical species by their characteristic spectral signatures. The mission of the HIRIS program is to demonstrate the utility of long-range, infrared, hyperspectral imagery to a wide array of nonproliferation, national security, and remote sensing problems.

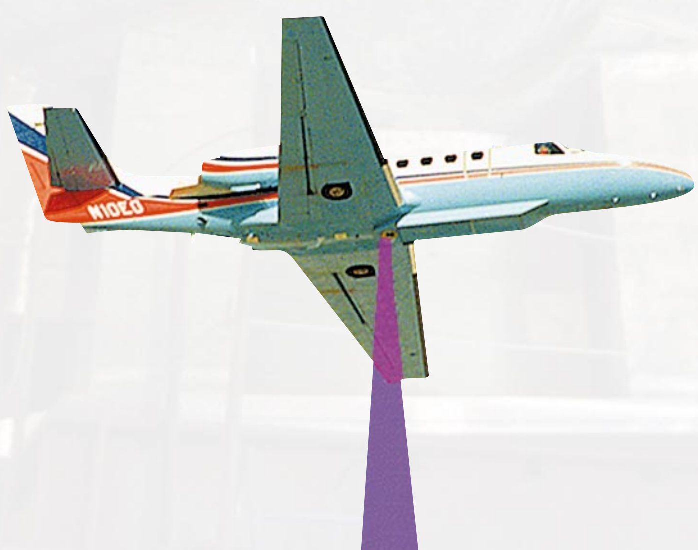
HERMES bridge inspection system wins R&D 100 Award

HERMES, a new ground-penetrating radar bridge inspection tool, was developed for the Federal Highway Administration by LLNL Engineering using its expertise in pulsed power and computational imaging. HERMES won an R&D 100 award for 1998.

The HERMES Bridge Inspector is able to diagnose the problems of deteriorating bridge decks and do it accurately, efficiently, nondestructively, and without closing bridges. Almost 30% of 600,000 large highway bridges in the U.S. are classified "deficient." With further development, HERMES holds promise for other concrete inspection problems, such as pavement, tunnels, and runways.

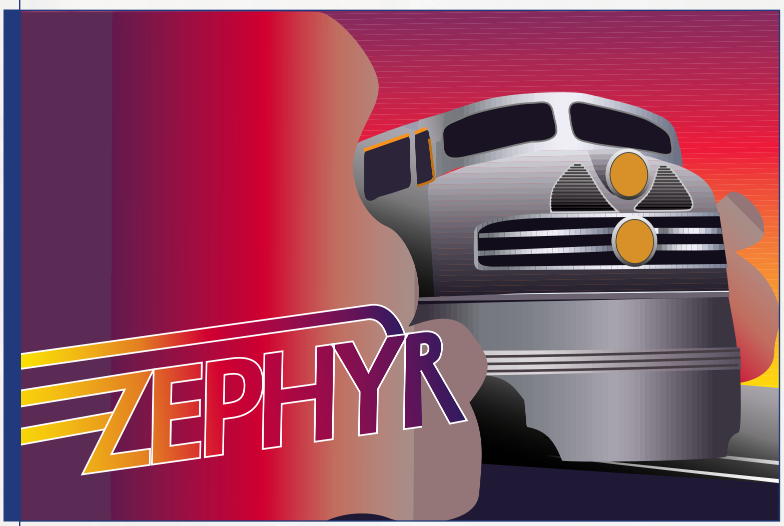


HIRIS produces spatial/spectral, temporal, and thermal information simultaneously, shown respectively left to right following the actual image of the Remote Sensing Test Range (far left). Below is the Cessna Citation jet that houses the HIRIS instrumentation.



E-commerce results show 90% faster time-to-market and 40% cost savings

Results from pilot programs in 1998 show that Zephyr, a new approach to paperless commerce and collaborative engineering, escalates a product's "time to market" by up to 90%, while saving 40% in costs. Zephyr, named after the famous California streamliner, uses e-mail and a Web browser to link small- and medium-sized manufacturers to LLNL for procurement and transmittal of electronic files. All Internet transactions are secure, that is, encrypted and password-protected.



Zephyr, a new approach to paperless commerce, links manufacturers to LLNL via e-mail and a Web browser.

Zephyr received a Best Practice Award from the Department of Energy and the Department of Defense, and a Best Manufacturing Process Award from the Office of Naval Research. It is currently being applied to procurements for the National Ignition Facility and has been linked to the Commerce at Light Speed (CALS) Working Group, U.S. Department of Commerce.

Next-Generation Internet teams LLNL Engineering with telecommunications partners

In November, Laboratory engineers joined counterparts at Nortel Networks, GST Telecommunications, and Sprint to build the West Coast leg of the Next-Generation Internet research network. This ultra-high-speed, high bandwidth network will link Seattle to San Diego with major nodes in Portland, San Francisco, and Los Angeles; the west coast link has been nicknamed the "SuperNet."

This partnership, known as the National Transparent Optical Network Consortium or NTONC, will be the primary testbed for advanced research by government agencies such the San Diego Supercomputing Center, universities such as the California Technology Institute, and private companies such as Microsoft, Boeing, Kaiser Foundation Health Plan, and others. Funding for the west coast leg is being provided by the Defense Advanced Research Projects Agency (DARPA); the three-year-contract began in the fall. When completed, the research network infrastructure will be worth over $120 million.

Business Accomplishments

In 1998, we continued to map our activities to our strategic plan. At our annual leadership off-site meeting, we refined our three high-level, long-term goals for the Directorate:

- Deliver on all program milestones, including the Laboratory's stretch commitments—safely.
- Become vital to the Laboratory by developing the breakthrough technologies upon which the next multimillion-dollar programs will be based, and develop the leadership team to realize and assume key responsibilities for such a program.
- Significantly increase Engineering's level of recognition within the national engineering community so that we can continue to attract and retain exceptional people.

Our key business accomplishments for 1998 relate to our key roles in the milestones of the Laboratory's five major programs, as well as immediate needs within our own internal structure and organization.

Meeting Milestones

First, Engineering met all critical Laboratory program milestones, including those involving the design and/or fabrication of large facilities such as the $1.2-billion National Ignition Facility and key nuclear weapons stockpile deliverables in conjunction with the successful W-87 flight testing. We also contributed significantly to the technical success of the extreme ultraviolet lithography project through our expertise in precision engineering technology.

Meeting these milestones required us to hire a significant number of employees, 177 in total. During this process, we experienced the tightest labor market in the Bay Area over the last 25 years, a situation that will probably continue in the next year.

Reducing Costs

Second, Engineering continued to improve its cost structure and increased the resources made available for core competency development. In FY98, Engineering's Organization Personnel Charge was 17.3%—4.9 points lower than FY95 when the OPC rate was originated at 22.2%. This change, combined with the Institution's G&A rate reductions, allowed the true cost of business for FY98 to be reduced by 6.8% from FY95.

In addition to overhead cost reductions, Engineering positioned itself to double the funding available for core competency development without increasing the cost to its customers. Entering FY98, this objective was largely achieved through a combination of organizational restructurings, divestment from facilities, and reduction in other capabilities no longer strongly coupled with the Laboratory's future mission. At the same time we invested $1.3 million for non-program-specific capital equipment, and developed an investment strategy for a continuing $3.0-million influx of funding for capital equipment in FY99. We plan to use these capital monies strategically in four areas: manufacturing and measurement, engineering computing resources, microtechnology, and general infrastructure. And we now have a structure that ensures that this capital funding will be ongoing.

Restructuring Technology Areas

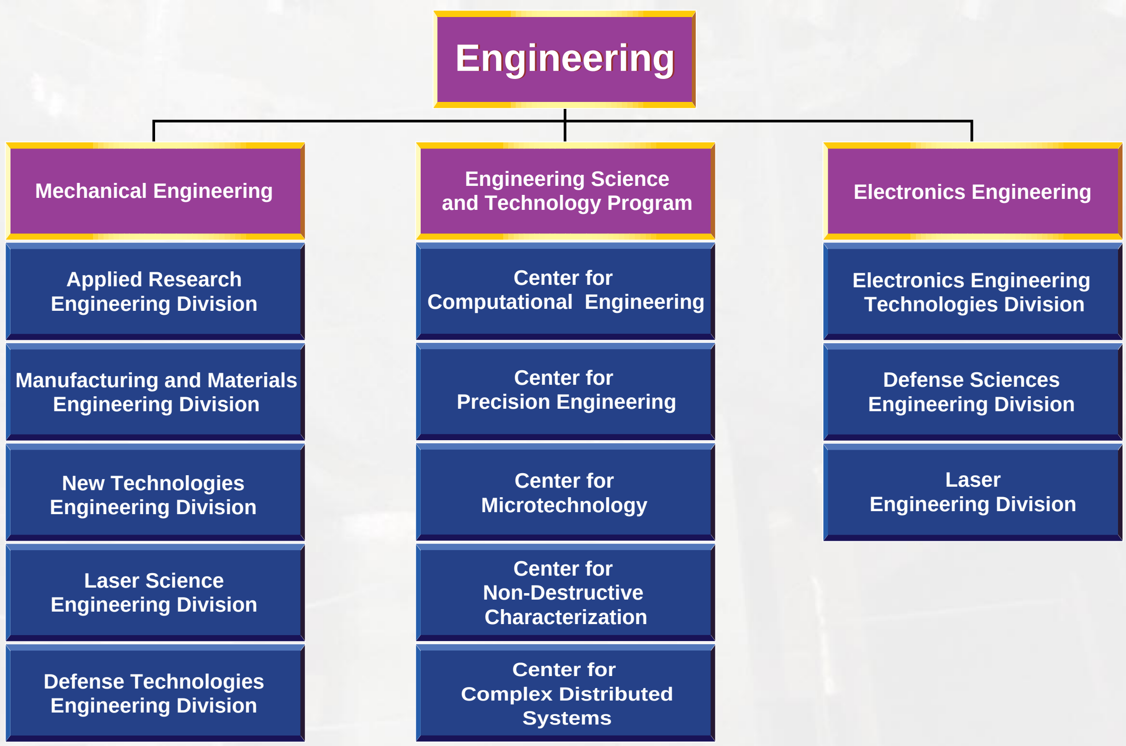
Third, Engineering underwent a significant restructuring of its technical investments operations. Starting in FY98, its nine thrust areas were consolidated into five Engineering Technology Centers exploring future innovations in computational engineering, microtechnology, precision engineering, non-destructive characterization, and complex distributed systems. These five centers, which collectively form the new Engineering Science and Technology program, now report to the Associate Director's office, rather than being embedded in one of the eight engineering divisions as the thrust areas were.

As part of this reorganization, the Centers have been given responsibility for the vitality and growth of the core technology each represents. These new units are specifically designed to bring together the best of both mechanical and electronics disciplines, creating a synergy that most organizations cannot. The expectations are that the Centers will produce breakthrough technology that solves compelling LLNL problems, that puts Engineering on the national map, and that fundamentally changes the way we go about doing our business. Formation of these Centers, and focusing all of Engineering's R&D budgets through these entities, completes the implementation of Engineering's long-term core technology strategy that was developed as part of our 1996 strategic plan.

A separate document, titled *Engineering Research, Development, and Technology,* provides a technical summary of our work in the centers and other key areas, that is, how we spent our money in FY98. This document, which is published annually, is to be distributed in the second quarter.

Improving Safety

Finally, Engineering amplified its effort to improve safety throughout the organization, in preparation for a full-fledged implementation of an Integrated Safety Management (ISM) system in FY99 throughout the Laboratory. This increased emphasis on safety has been accomplished through focused management attention and commitment to safe and effective operations, an expansion of Engineering's grass-roots safety program, and other programs. Overall, our safety record improved by reducing the severity of incidents over FY98 by another 23%, as measured by the number of lost and restricted work days. In FY99, we will continue to focus on safety as we develop a Directorate-wide training program.



Honors and Awards

R&D 100 Awards

Each year *R&D Magazine* selects the 100 most technologically significant products and processes for "Oscars" of applied research. The R&D 100 judges look for products or processes that promise to change people's lives by significantly improving the environment, health care, or security.

Winners are chosen by the editors of the magazine and a panel of 75 experts in a variety of disciplines. Corporations, government laboratories, private research institutes, and universities throughout the world vie for these awards. In 1998, the following Engineering employees won awards:

High-Performance Electromagnetic Roadway Mapping and Evaluation System (HERMES)

Stephen Azevedo, Gregory Dallum, Richard Gilliam, George Governo, Jose E. Hernandez, Holger Jones, Ming-Li Liu, Jeffrey Mast, Scott Nelson, Tom Rosenbury, Robert Stever, Thomas Story, Mark Vigars, John Warhus, Patrick Welsh, Steven Chase

Laser-Peening for Metal Life Protection

Steven Telford, James Wintemute

Light-Lock Optical Security System

Robert Clough, Robert Stoddard, Karla Hagans, Richard Main

OptiPro Acoustic Emission Detector

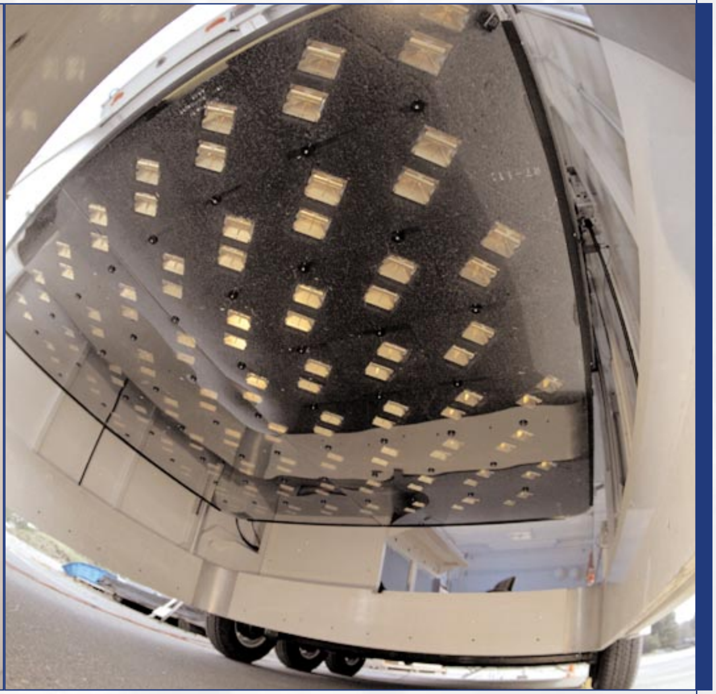
Mark Piscotty, John Taylor, Kenneth Blaedel

Special Honors

Institute of Electrical and Electronics Engineers

Fellows: Jim Candy for "contributions to model-based acoustic signal processing," Bob Deri for "contributions to photonic devices and integration on compound semiconductors"

Senior Members: Karl Krause, Karla Hagans



A fisheye-lens view of HERMES radar modular array from inside (left) and from under the rear door (right).

Director's Performance Awards

Several times each year, the Director of Lawrence Livermore National Laboratory honors teams of employees who have made outstanding technical contributions to LLNL. In 1998, the following Engineering employees won awards:

Counterproliferation Analysis and Planning System (CAPS)
Heather Walsh

Active and Passive Computer Tomography
G. Patrick Roberson, Harry Martz, Sailes Sengupta, Gene Ford, Dennis Goodman, Jessie A. Jackson

Airborne Laser Illuminators
Joel Speth, Scott Mitchell, John Lang, Dennis Maderas

KDP (Potassium Dihydrogen Phosphate) Crystal Growth
Warren Bell, Martin Dehaven, D. Lynn James, Dick Spears, Russ Vital, Thomas L. Clark, Lavern W. Morris, Gayle B. Johnson

Beamlet Engineering and Operations Support
William C. Behrendt, Gene Frieders, Thomas A. McWilliams, Norman D. Nielsen, Guy H. Robitaille, Terry D. Schwinn, Timothy L, Weiland, Michael E. Werve

High-Average-Power Visible Solid-State Lasers
Isaac L. Bass, Curtis W. Cochran, Ernest Dragon, Gaylen V. Erbert, Glen Huete, Vernon Keith Kanz, Angela M. Niles

Nuclear Weapons Information Project
Henry S. Ames

Vault Access Link
John P. Cornish, Dean T. Rippee

First Large-Scale Demolition and Salvage Contract; B435 and B431 Demolition and Salvage Projects
Henry H. Bell, Jr.

Other Awards

Institute of Electrical and Electronics Engineers, Executive Fellowship
Stan Trost

American Society of Mechanical Engineers, Curriculum Innovation Awards Committee
Moe Dehghani

American Society of Precision Engineers, Board of Directors
Debra Krulewich
Jeff Carr

American Nuclear Society, Secretary of Robotics and Remote Systems Division
Al DiSabatino

National Mechanical Engineering Evaluator, Accreditation Board for Engineering and Technology Programs; National Mechanical Engineering Department Heads Committee
Moe Dehghani

Mexican-American Engineers and Scientists, Board of Directors
Jose M. Hernandez

Appointment to Defense Advanced Projects Research Agency; Two-year Washington assignment
Abe Lee

Top Optical Design (one of three), Competition sponsored by Optical Society of America for the International Optical Design Conference
Lynn Seppala

DOE Award for Seismic Safety
Tom Nelson

DOE Appreciation Award for Nuclear Materials Management Forum
Joan Accardo

DOD Lifecycle Cost Reduction Award
Tom Rosenbury

Journal of Structural Engineering, Editor
Dave McCallen

Commendation for Excellence in Technical Communications from *Laser Focus World*
Dave Aikens

Society for Technical Communication Regional Award
Dennis Chan

Council of Communication Management, Board of Directors
Carol Gerich

Patents

Halbach Array DC Motor/Generator
Gary R. Dreifuerst
Bernard T. Merritt

Plasma-Assisted Catalytic Reduction System
Bernard T. Merritt,
George E. Vogtlin,

Diesel NO_2 Reduction by Plasma-Regenerated Absorbent Beds
George E. Vogtlin

Microminiaturized Minimally Invasive Intravascular Micro-Mechanical Systems Powered and Controlled Via Fiber-Optic Cable
Karla Hagans
Abraham P. Lee
William J. Benett

Pulsed Hybrid Field Emitter
Stephen E. Sampayan

Critical Illumination Condenser for X-Ray Lithography
Lynn G. Seppala

Apparatus for Precision Micromachining with Lasers
Ernest P. Dragon

Hybrid Slab-Microchannel Gel Electrophoresis System
Jackson C. Koo

Selective Document Image Data Compression Technique
Chi-Yung Fu

Ambient Temperature Cadmium Zinc Telluride Radiation Detector and Amplifier Circuit
Anthony D. Lavietes

Precision Replenishable Grinding Tool and Manufacturing Process
Kenneth L. Blaedel
Pete J. Davis

Amorphous Diamond Films
Steven Falabella

Micromachined Actuators/Sensors for Intratubular Position/Steering
Abraham P. Lee
Peter A. Krulevitch
Jimmy C. Trevino

Light-Weight DC to Very High Voltage DC Converter
Robert L. Druce
Hugh C. Kirbie

Separators
Thomas C. Kuklo

Interlayer Toughening of Fiber Composite Flywheel Rotors
Steven J. Deteresa
Scott E. Groves

Fabrication Method For Miniature Plastic Gripper
William J. Benett
Peter A. Krulevitch
Abraham P. Lee
James A. Folta

Automatic Position Calculating Imaging Radar with Low-Cost Synthetic Aperture Sensor for Imaging Layered Media
Jeffrey E. Mast

Soliton Quenching NLTL Impulse Circuit with a Pulse Forming Network at the Output
Gregory E. Dallum

High Precision Redundant Robotic Manipulator
Kar-Keung David Young

Method for Formation of Thin Film Transistors on Plastic Substrates
Randy C. Aceves

Microvalve
Abraham P. Lee
Peter A. Krulevitch
Jimmy C. Trevino

High Density, Optically Corrected, Micro-Channel Cooled, V-Groove Monolithic Laser Diode Array
Barry L. Freitas

Process for 3D Chip Stacking
Vincent Malba

Ultra Wideband Ground Penetrating Radar Imaging of Heterogeneous Solids
Jeffrey E. Mast
John P. Warhus

Encephalolexianalyzer
Farid U. Dowla

Image System for Three Dimensional, 360 Degree, Time Sequence Surface Mapping of Moving Objects
Shin-Yee Lu

New Ventures: Xtreme Engineering

From Microscale to Ultrascale

Engineering at LLNL has a reputation for doing the impossible, as it develops its technologies to meet critical national issues. Today Engineering is pioneering technologies that extend the range of solutions from microscale to ultrascale. We call these poles **"Xtreme Engineering"** because these new areas of expertise stretch the already wide breadth of LLNL's technology portfolio.

Engineers work with others at the Laboratory and in the Department of Energy to address national priorities—demanding even smaller parts, faster times, greater power, more complexity, and higher precision. They have developed the world's smallest biomedical instruments and now are helping to build the National Ignition Facility, the world's largest laser. The following examples illustrate LLNL engineering solutions to challenges in the micro and ultra worlds.

Microscale Systems

The next generation of medical diagnostic instruments will integrate electronics with fluids on microfabricated chips. Working with the M. D. Anderson Cancer Center and UC Berkeley, mechanical engineer **Peter Krulevitch** estimates that his team is one year away from applying this technology to a hand-held instrument capable of separating and identifying cells.

Meanwhile, mechanical engineer **Robin Miles** and her team are building a device to purify and concentrate airborne pathogens for more efficient detection.

Their designs use 20- to 200-micrometer-deep fluid channels etched in glass substrates with patterned electrodes for identifying and manipulating biological particles. (A human hair is about 100 micrometers in diameter.)

Another thrust in microscale systems is developing miniaturized total analysis systems on a single chip. Most of these systems are targeted for diagnostic applications with the intent of speeding up assays, reducing sample size, and even producing small portable instruments for home use.

Amy Wang is using her electrical engineering skills to advance these miniaturized systems. She is studying both acoustic forces and ultrasonic waves as a means to mix, transport, and sense the tiny particles in these revolutionary microfluidic systems.

Very-High-Speed Diagnostics

A second of time is "forever" to mechanical technician **Rob Costa** and electronics engineer **Dean Lee**. Their work is measured in picoseconds or one-trillionth of a second. The two work as a team to design and develop diagnostics that will support fusion experiments in the target chamber for the National Ignition Facility.

Until NIF is built, they develop diagnostics and support experiments on the Nova laser at LLNL. These findings will improve the technology of streak cameras, gated imagers, digital cameras, and other diagnostic components.

Shown left to right, engineers Robin Miles, Peter Krulevitch, Amy Wang, and Dean Lee (with technician Rob Costa holding instrument).

Defense technologies also depend on extremely high-speed diagnostics. **Paul Sargis**, an electronics engineer, specializes in developing high-speed measurement systems that use advanced fiber-optic and microwave technologies.

He is currently developing a diagnostic device to measure surface speeds over 4000 mph in a microsecond timeframe. Here Sargis is shown next to the prototype velocimetry electronics that he designed and used on recent high-explosives tests.

Ultra-Precision Tools

The National Ignition Facility will depend on optics that set new standards for quality and purity. Mechanical engineer **Rick Montesanti** and mechanical engineer associate **Sam Thompson** applied their expertise and experience in precision engineering to guide a commercial design of a new ultra-precision machine tool critical for fabricating a unique class of optics needed for NIF. (Ultra-precision machine tools can be one- to two-orders-of-magnitude more precise than those industry calls high-precision tools.)

The new machine tool, a diamond fly cutter, will produce the final surfaces on all crystalline optics used in the 192 laser beams of NIF. Aside from helping NIF, the work advanced a company's position as a world-class machine tool builder.

The same increased precision in manufacturing is being demanded by other LLNL programs. Requirements for many of these precision parts are being specified in terms of the allowable frequency distribution of errors on the final machined part. Before work by LLNL, no precision method existed for designing or selecting machine tools to manufacture these parts.

Mechanical engineer **Debra Krulewich** has developed advanced methods for correlating the behavior of a machine's subsystems to their "signature" or impact on the accuracy of a finished part. With this new method, errors can be predicted, and changes to the machine's subsystems can better match finished part requirements.

Shown left to right, engineers Paul Sargis, Rick Montesanti, (with Sam Thompson, mechanical engineer associate) and Debra Krulewich.

Monumental Structures

Structural mechanics engineer **Dave McCallen**, with LLNL seismologists and UC Berkeley engineering faculty, is performing large-scale computer simulations to determine how various mammoth structures will respond during earthquakes in California. His detailed computer modeling already has helped CalTrans fine-tune its $50-million retrofit of the 24-580-980 highway interchange in Oakland, California.

Now he is studying how long-span arch bridges along California's coast—like the San Francisco Bay Bridge—will respond to earthquakes. His studies will improve structural designs and probably save lives in the "Big One."

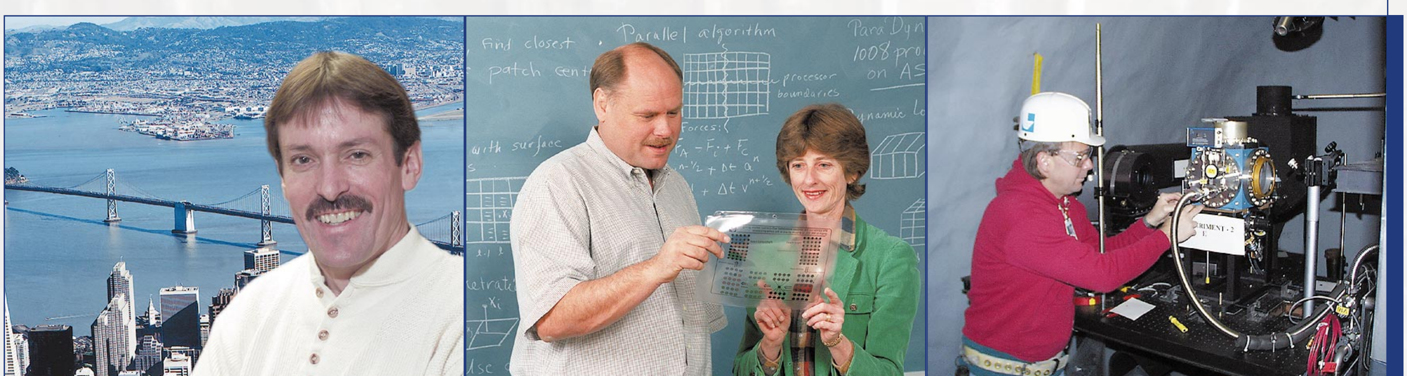
LLNL, a pioneer in monumental-scale computing since our founding, is now utilizing massively parallel computers that provide thousands of processors to calculate engineering problems with hundreds of millions of sets of data. Electrical engineer **Tony De Groot** and computational physicist **Carol Hoover** design innovative numerical methods for ParaDyn, a parallel version of the popular DYNA3D computer code developed at LLNL that is now used worldwide as a materials deformation code for structures of all sizes.

ParaDyn performs calculations in less than a day that required over a month before. Hoover and De Groot report that ParaDyn and massively parallel computers are already providing breakthroughs in the defense, transportation, and manufacturing industries.

Very-Large-Scale Experiments

Today we cannot use actual testing to assure that the nation's nuclear weapons stockpile is safe and reliable. Instead, the Laboratory conducts "tests" with computer simulations or on parts of technical components that already exist.

Mechanical engineer **Bret Knapp** leads a group whose work includes the Lab's Big Explosive Experimental Facility. His group builds very-large-scale experiments for the scientists who are charged with ensuring the safety and reliability of the high-explosives components for existing weapons. After creating sketches or computer-generated designs, they make parts that can be tested at the Lab's Site 300 or at the Nevada Test Site.



Shown left to right, engineers Dave McCallen, Tony De Groot (with physicist Carol Hoover), and Bret Knapp.

The Stanford Linear Accelerator will make scientific history this summer when it begins high-energy accelerator experiments on the grand scale aimed at unraveling how the universe evolved after the Big Bang. This $300-million UC project, called the B Factory, will use many machine components built at LLNL.

Mechanical engineer **Johanna Swan** designed, built, and tested the final focusing quadrupole magnets that will guide the accelerator beam before it goes into the detector. The magnet she worked on is unique because it used an unprecedented coil design to shape the magnetic field to meet the most stringent requirements on the B-Factory project. Swan is shown below with a cross- section design for her five-foot-long magnet.

Very-Large-Scale Systems

The world's most powerful laser—now under construction at LLNL—will be controlled by one of the most complex computer systems. Shown at the prototype operator console are electrical engineers **Paul Van Arsdall**, system manager of the design team, and **Vicki Miller Kamm**, in charge of the alignment computer subsystem that controls some 9,000 motors attached to beam transport optics.

The integrated system of over 500 computers will control some 60,000 points for every shot, including mirrors, lenses, motors, sensors, cameras, amplifiers, pulse power, and diagnostic instruments. Working with the harmony of an electronic symphony, the control system will ensure that the laser's 192 beams propagate a 20-ns-long burst of light precisely toward a microscopic fusion target.

A global-scale concept that could revolutionize intercontinental flight and access to space is ready to jump from the drawing board for aerospace engineer **Preston Carter.** His new aircraft, called HyperSoar, could fly 6700 mph and reach an altitude of 200,000 feet, getting passengers to any destination on the planet in under two hours.

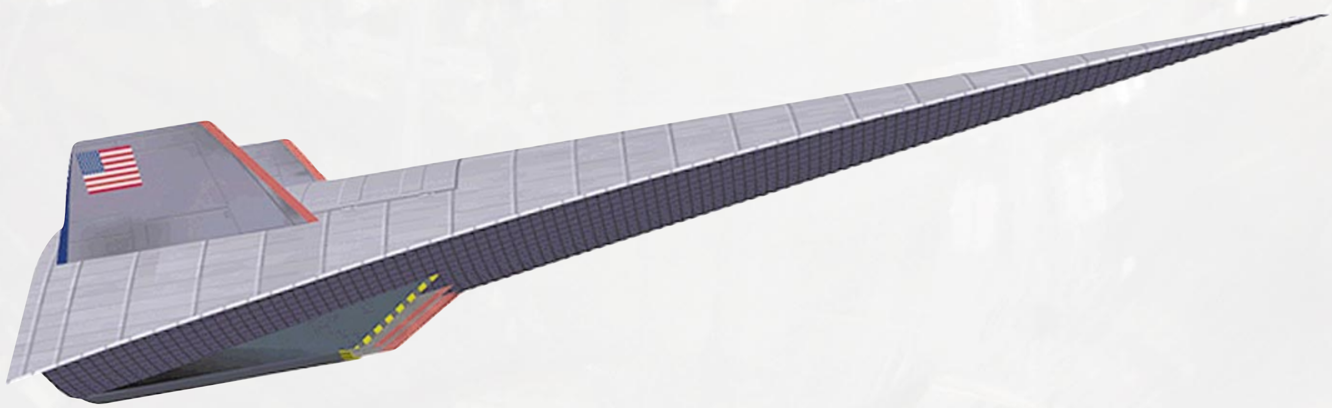
The key to HyperSoar is the skipping motion of its flight along the upper edges of the Earth's atmosphere that avoids the heat of the lower layers. Most likely to be first used for military applications, HyperSoar is under serious discussion for development of the first prototype.

Shown left to right, engineers Johanna Swan, Paul Van Arsdall, Vicki Miller Kamm, and Preston Carter.

Engineering Tomorrow: 1999 Priorities

In the coming year, our key challenges are to:

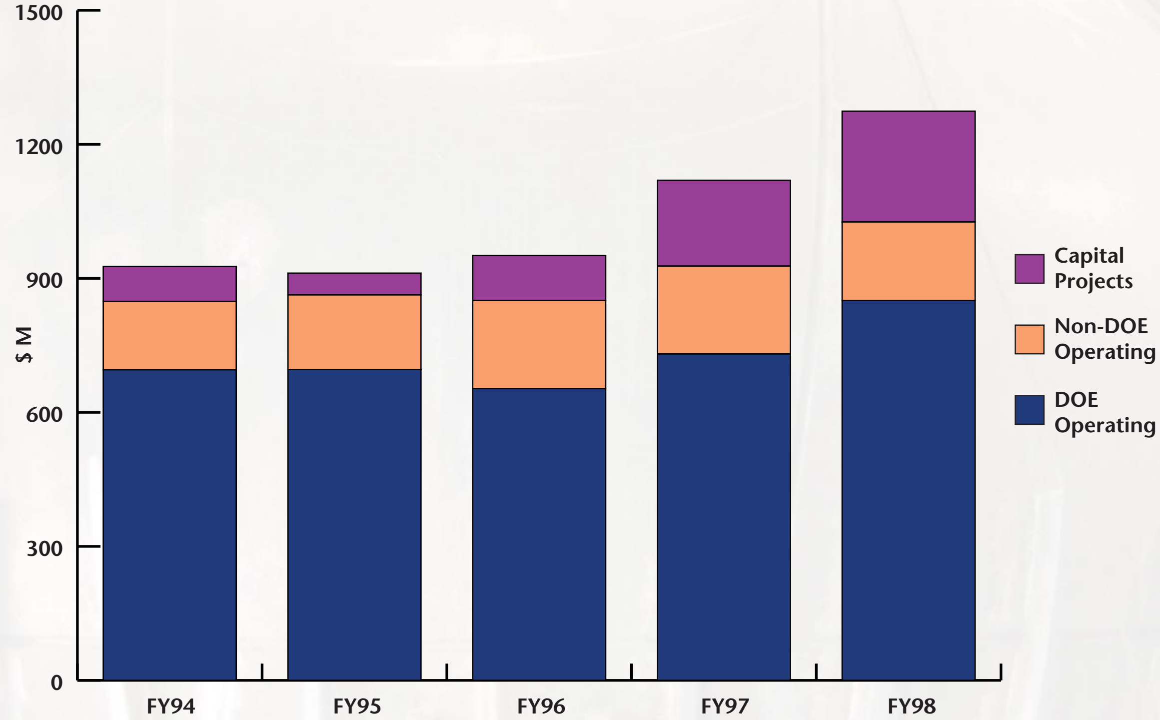
- Continue to deliver on all program milestones safely, including the Laboratory's stretch commitments. In 1999, this will imply both emphasis on project deliverables, as well as significant and measurable improvements in our safety records.
- Significantly increase Engineering's level of recognition within the national engineering community so that we can continue to attract and retain exceptional people.
- Complete the implementation of our technology strategy, including selecting the new leadership team to spearhead our Engineering Technology Centers. This venture will also mean that we will need to lay the foundation for success—developing breakthrough innovation that solves compelling LLNL problems, that significantly expands Engineering's level of recognition nationally, and that fundamentally impacts the way we do our business.
- Increase our flexibility so that we can position ourselves to seamlessly respond to the eventual rampdown of major Laboratory projects, and to attain and sustain a wisely planned, healthy level of capital and core competency investment.
- Strengthen our leadership team and initiate a strong executive and emerging leadership program.
- Help the Laboratory capture the next multi-hundred-million-dollar program and have on board the leadership team to assume key roles in this new program.



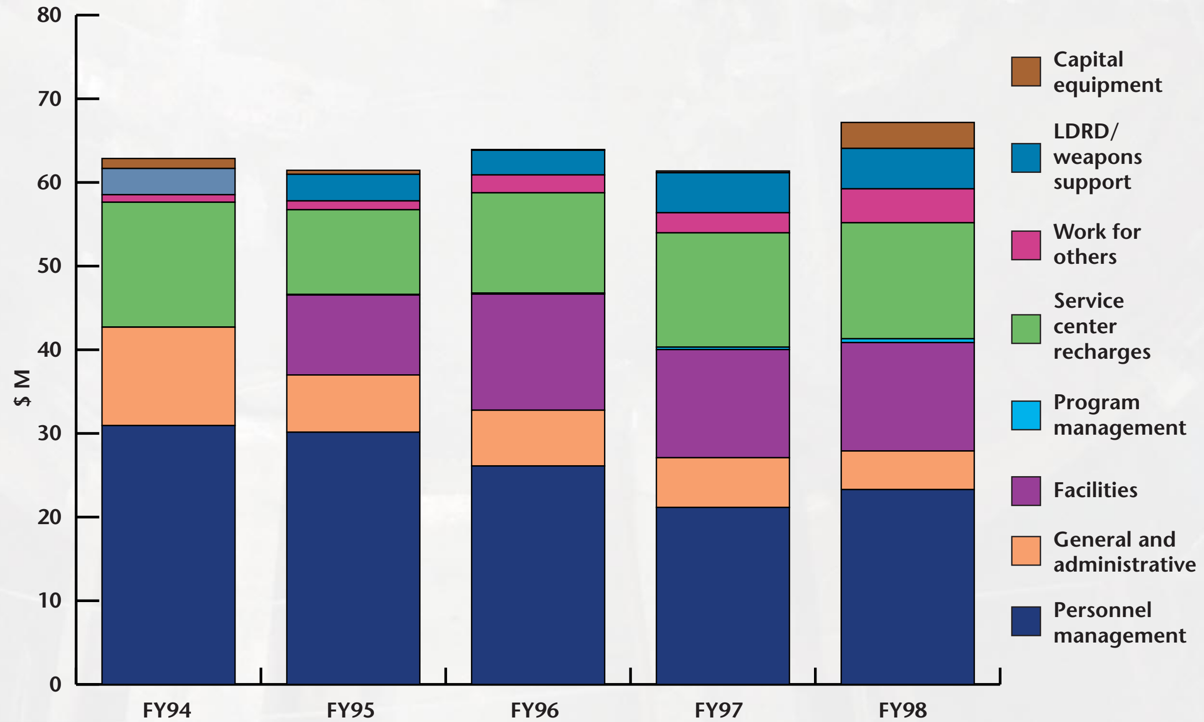
HyperSoar, the world's fastest aircraft, would travel 6700 mph and reach anywhere on earth in two hours. This concept would most likely see military applications, then commercial.

Appendices

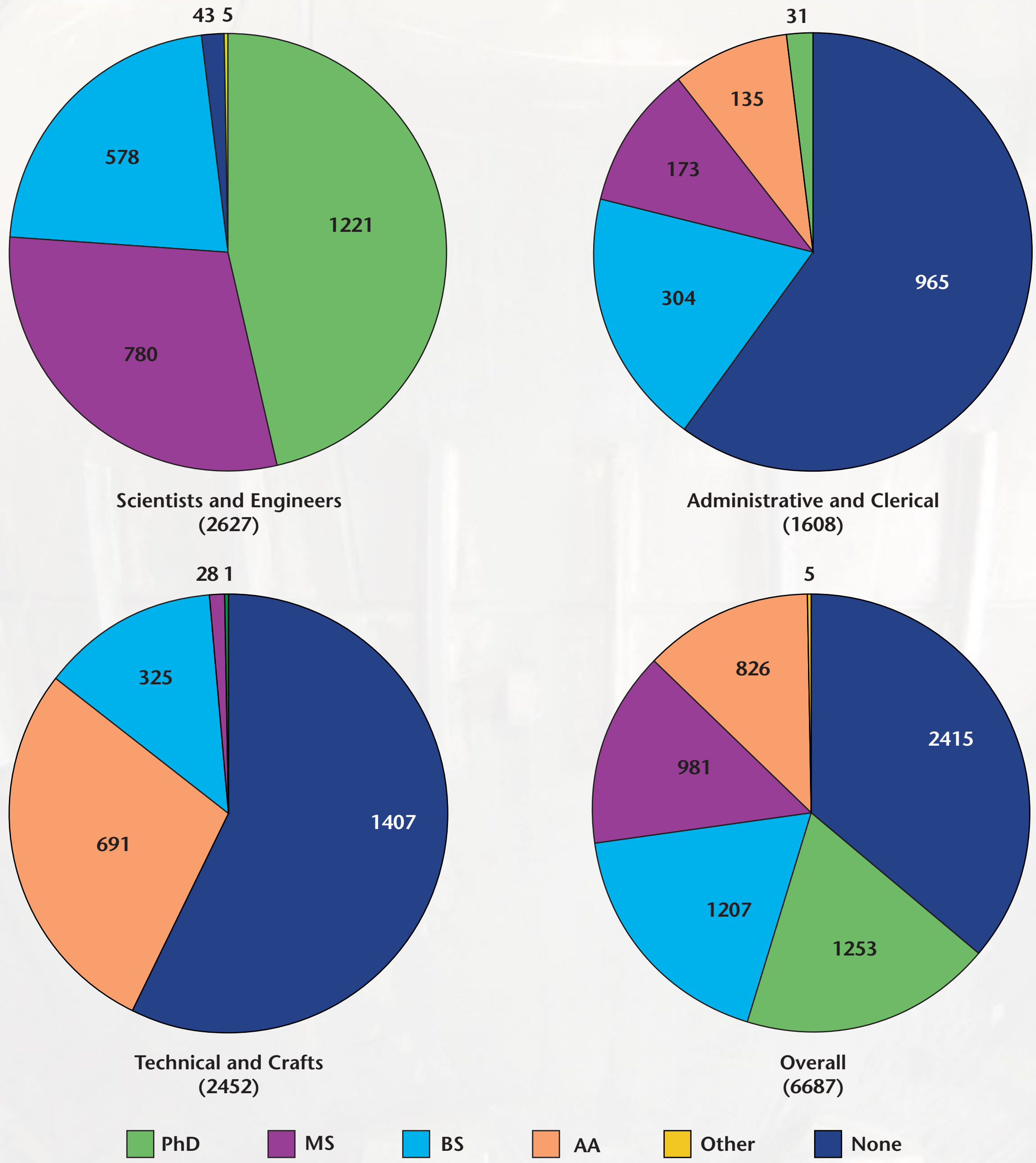
LLNL 5-Year Funding Trend



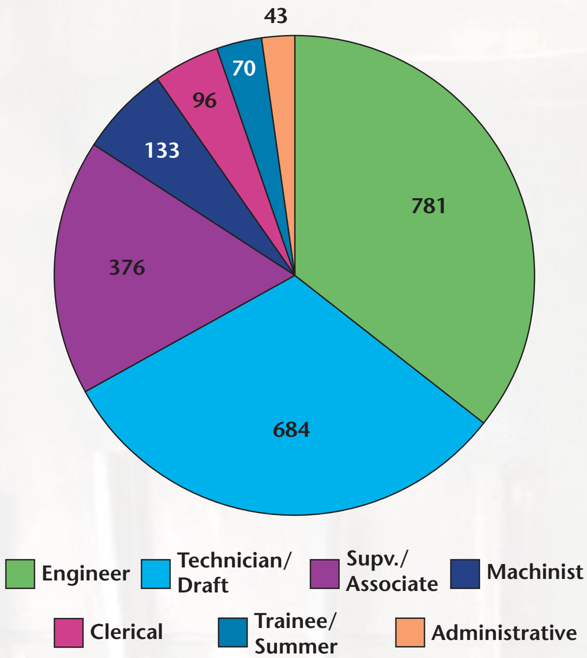
Engineering 5-Year Expenses



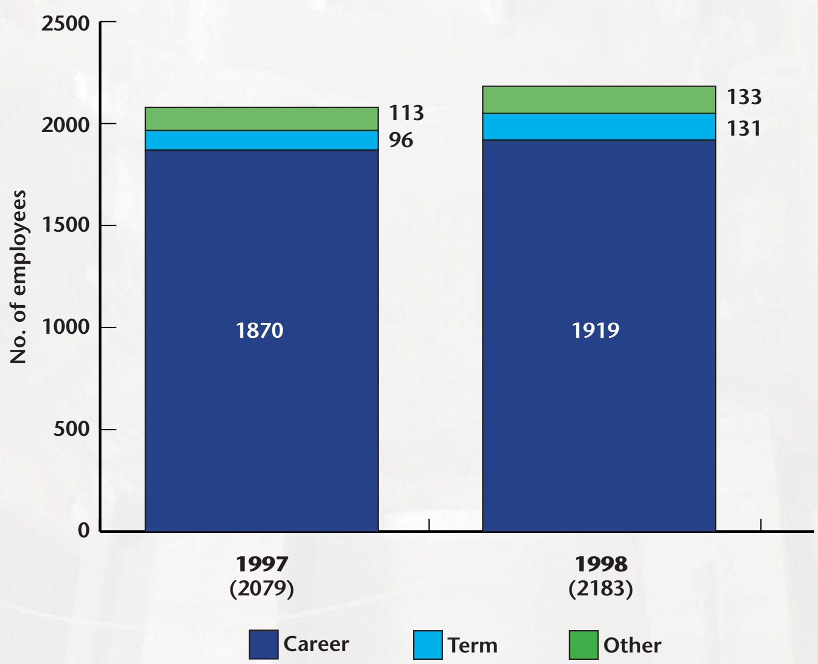
LLNL Staffing Profile (as of 9/30/98)



Engineering Staffing Profile (as of 9/30/98)



Engineering Staffing Growth (as of 9/30/98)



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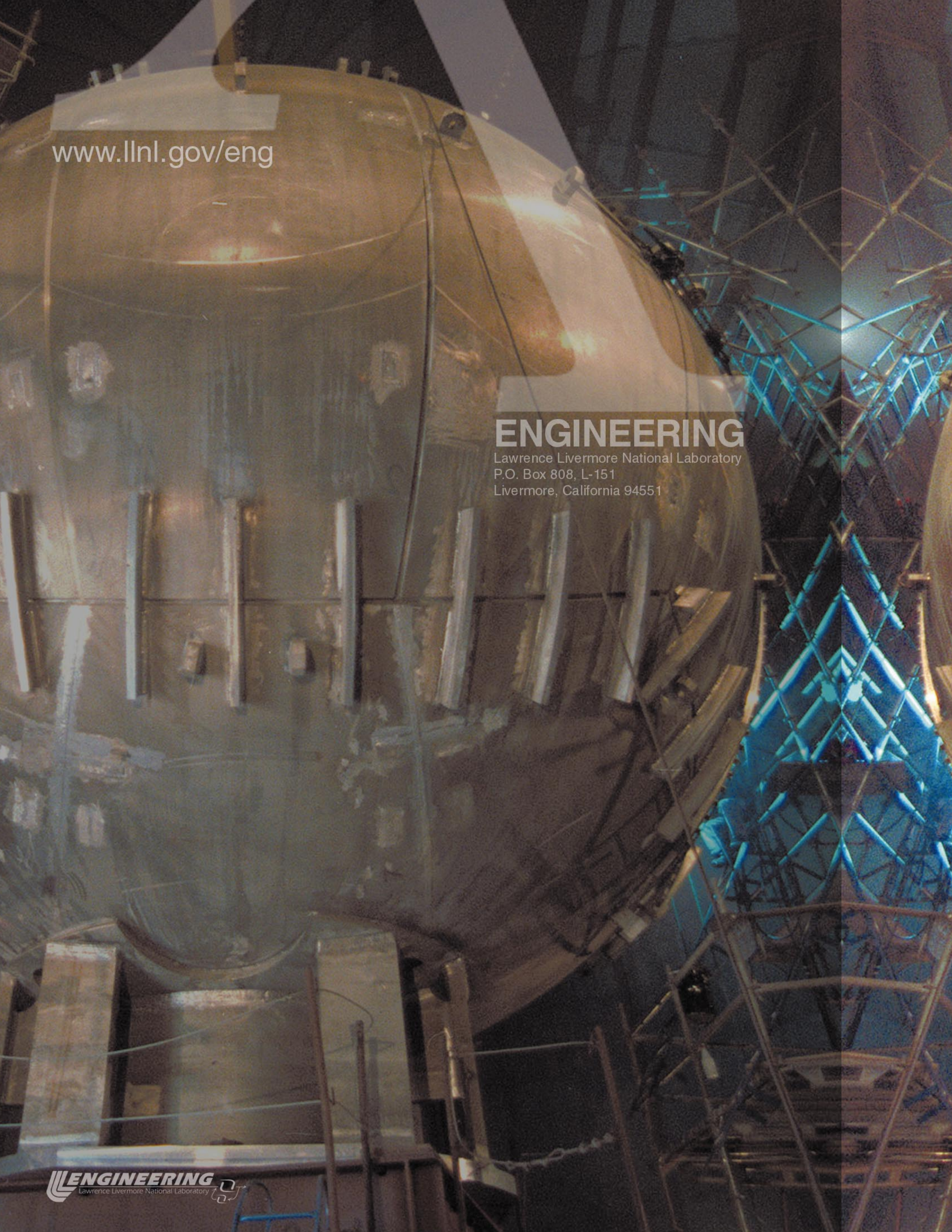
Work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract W-7405-Eng-48.



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